Catching of spiders in shallow subterranean habitats in the Czech Republic

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Abstract. Spiders occurring in soils and fissured rocks were investigated using pipe traps. Four microphthalmic species, namely *Hahnia microphthalma*, *Porrhomma egeria*, *P. microps* and *P. cambridgei* were collected. *Hahnia microphthalma* is reported from the Czech Republic for the first time. The importance of collecting material by complex pipe traps (consisting of a perforated pipe and a set of removable cups) to record the depth distribution of spiders in subterranean habitats is stressed. The importance of the soil and fissure network formed by sandy marlite bedrock and of alluvial soils for the life of subterranean spiders is documented.

Keywords: alluvial soil, microphthalmy, pipe traps, sandy marlite, troglomorphism

For humans, caves are more accessible than other subterranean habitats. Much of what we know about subterranean biology comes from the study of caves, partly because of the adventure and excitement of visiting and exploring caves, which are certainly more exciting than visiting, for example, talus slopes (Culver & Pipan 2009). Terrestrial shallow subterranean habitats are formed in soil, rock mantle formed in bare and forest scree, slope and alluvial sediments and in fissured rock and cave entrances (Culver & Pipan 2014). A depth of about 10 m represents the natural border between shallow and deep subterranean habitats (Novak et al. 2012, Růžička et al. 2013). Our knowledge concerning invertebrates that live only several metres under the surface is very limited.

Many subterranean invertebrates display similar morphologies that have evolved convergently under similar selective pressures imposed by the subterranean environment. Subterranean spiders show typical morphological changes known as troglomorphisms: depigmentation, microphthalmy and lengthening of the legs (Culver & Pipan 2009).

Arachnological research into shallow subterranean habitats has a long tradition in the Czech Republic. Independently of Juberthie & Delay (1981), Růžička (1982) started to investigate invertebrates living in talus slopes using board traps. Numerous surprising findings have been reported since, including five taxa new to science, and twelve species of arthropods new to the Czech Republic (Růžička & Klimeš 2005). *Wubanoides uralensis* (Pakhorukov, 1981) (respectively *Wubanoides uralensis lithodytes* Schikora, 2004), was recorded for the first time in Europe and several troglomorphic populations/taxa have been described (Růžička 1988a, 1998, 2011). His research has documented that freezing talus slopes represent a classic example of a palaeorefugium that significantly contributes to the protection and maintenance of regional landscape biodiversity (Růžička et al. 2012).

The main component of traps used by López & Oromí (2010) for catching invertebrates in shallow subterranean habitats on the Canary Islands is a 75 cm long plastic pipe with an inner diameter of 11 cm. Many small holes (5-7 mm in diameter) are drilled along its surface, and a bottle containing preservation fluid (and bait) is lowered inside on a nylon cord. The pipes are installed vertically into holes in a suitable terrain. This kind of trap is a modification of a similar pipe used by Gers (1992). Barranco et al. (2013), Ortuño et al. (2013) and Jiménez-Valverde et al. (2015) used such traps to investigate invertebrates in stony slopes and river deposits in continental Spain; Nitzu et al. (2014) used a similar trap in Romania.

Schlick-Steiner & Steiner (2000) constructed a trap consisting of a perforated pipe and a set of removable plastic cups situated on a central-thread metal axis. Through this arrangement, the cups collect animals entering the tube through holes at particular depths. Using these complex pipe traps (with a length of 95 cm), Laška et al. (2011) studied the distribution of spiders in soil profiles and Rendoš et al. (2012) studied the distribution of invertebrates in limestone scree slopes. The design of perforation varies from a horizontal line of holes, to a network of holes up to horizontal cuttings accompanied by holes (Fig. 1a–c). The aim of this present study was to test the performance of pipe traps in soils and crevice systems.

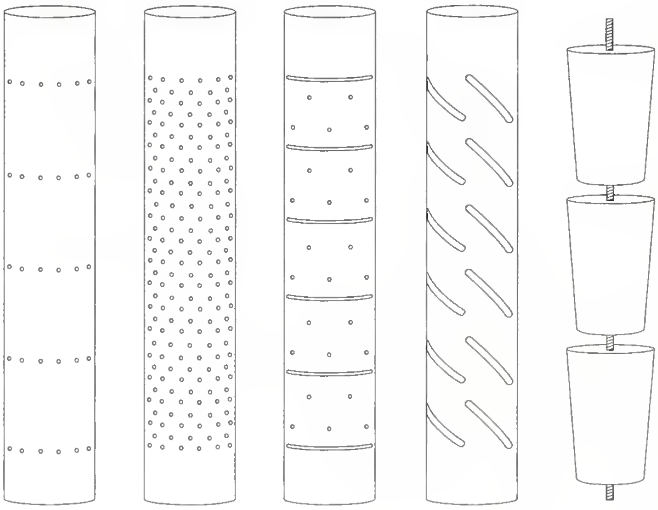

Fig. 1: Design of perforation; **a.** Schlick-Steiner & Steiner (2000); **b.** López & Oromí (2010); **c.** Laška et al. (2011); **d.** our design and a set of cups

Material and methods

Sampling. Six pipe traps (one per site) were deployed from 2013 to 2015, and were emptied twice a year. The plastic pipes have an inner diameter of 7 cm, and are perforated with a system of oblique cuts 5 mm wide (Fig. 1d). This design has been registered at the Czech Industrial Property Office under No. 36420. Plastic cups were mounted onto a metal-thread rod at

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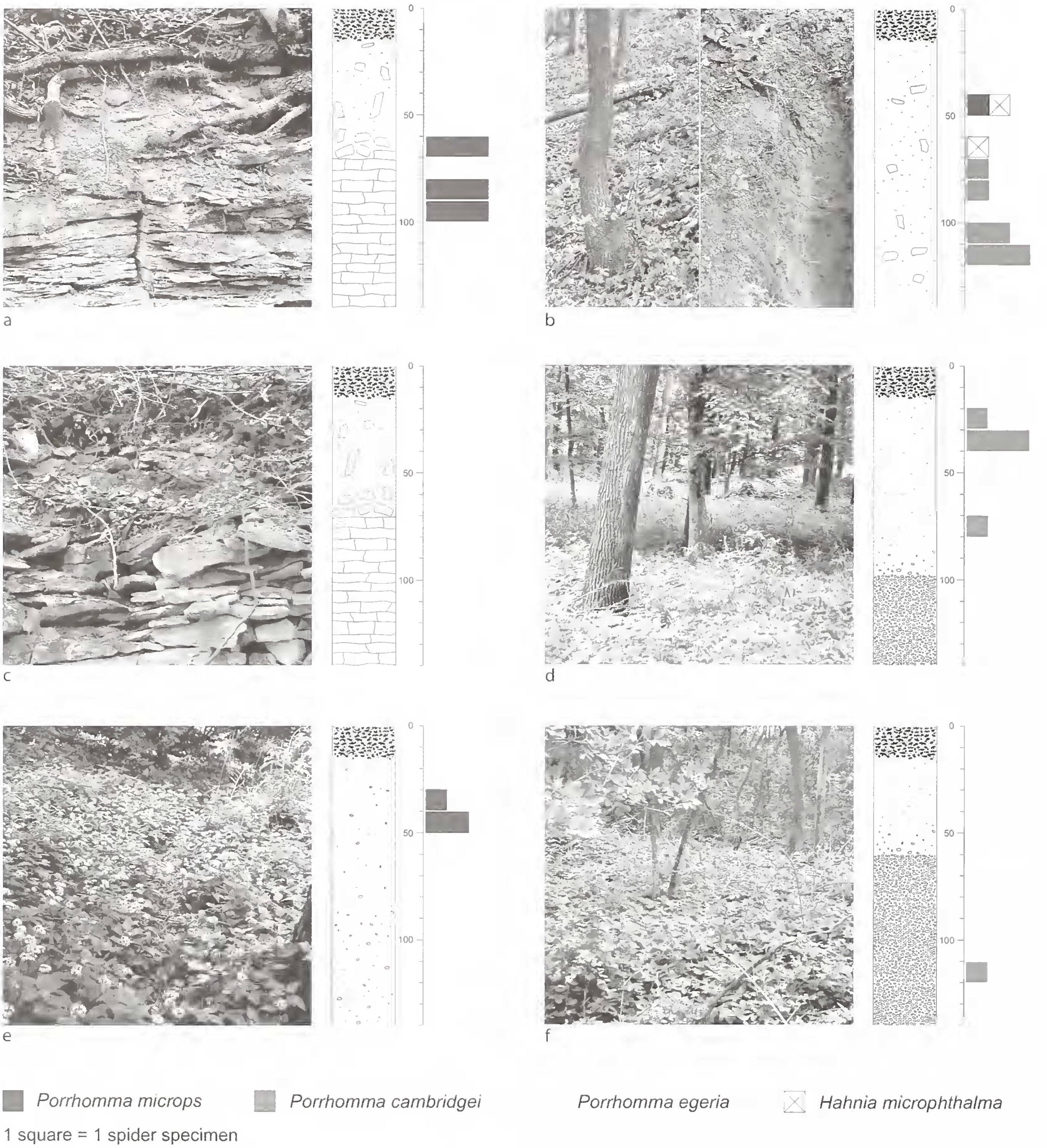

Fig. 2: Study sites with terrain profile and the depth-dependent occurrence of microphthalmic species; **a.** site SM-1, upper margin of a sandy marlite slope; **b.** site SM-2, lower margin of a sandy marlite slope; **c.** site SM-3, sandy marlite table hill; **d.** site AS-1, lowland forest; **e.** site AS-2, lowland forest; **f.** site AS-3, lowland forest

10 cm distances and contained a mixture of 7 % formalin and 5 % glycerol, plus a few drops of detergent (Růžička 1988b). In the final version, we used plastic or brass components to avoid damage to material caused by rust. We installed these traps in excavated trenches in sandy marlite terrains, or in boreholes (15 cm in diameter) in lowland forests, the deepest reaching 160 cm below the surface. The free space around the trap was filled by excavated material or – in the case of boreholes – by a mixture of excavated material and artificial rubble (Keramzit) or starch-based packing peanuts.

Study sites. Traps were installed in sandy (arenaceous) marlite (SM) terrains, and in alluvial soils in lowland forests (AS) (Figs 2a–f).

SM-1. Jenišovice-Mravín (49.9446°N, 16.0522°E, 335 m a.s.l.). On the upper margin of a sandy marlite slope at the border between a deciduous forest and a lucerne field: 0-60 cm stony soil, 60-100 cm fissured rock (Fig. 2a). The pipe with ten cups at a depth of 10-100 cm operated from 25 October 2013 to 29 September 2015. The spider assemblage of adjacent open habitats was studied by Dolanský (2002).

SM-2. The same locality as SM-1, 50 m apart (49.9445°N, 16.0516°E, 315 m a.s.l.), at the lower margin of a sandy marlite slope covered by deciduous forest (Fig. 2b). The whole profile studied consisted of a clay soil. The pipe with nine cups at a depth of 40-120 cm operated from 25 October 2013 to 29 September 2015.
SM-3. Kounov (50.2320°N, 13.6899°E, 515 m a.s.l.). Mixed forest on a sandy marlite table hill, 15 m from a quarry wall: 0-70 cm stony soil, 70-140 cm fissured rock (Fig. 2c). The pipe with 14 cups at a depth of 10-140 cm operated from 1 November 2013 to 25 September 2015.
AS-1. Lednice (48.7867°N, 16.8448°E, 170 m a.s.l.). Lowland forest with rich herb and shrub vegetation (Fig. 2d): 0-90 cm clay soil. Fluctuating water table. The pipe with nine cups at a depth of 10-90 cm operated from 29 June 2014 to 17 May 2015.
AS-2. Znojmo (48.8466°N, 16.1033°E, 220 m a.s.l.). Lowland forest with rich herb and shrub vegetation (Fig. 2e): 0-70 cm sandy soil. The pipe with seven cups at a depth of 10-70 cm operated from 20 August 2014 to 11 May 2015.
AS-3. Pardubice (50.0458°N, 15.7727°E, 220 m a.s.l.). Lowland forest with rich herb and shrub vegetation (Fig. 2f): 0-60 cm alluvial soil, 60-160 cm sand. The pipe with 16 cups at a depth of 10-160 cm operated from 15 May 2014 to 23 September 2015.

Results and discussion

Spiders

In total, we captured 335 spider specimens belonging to 32 species (Appendix): 155 spiders belonging to 20 species at site SM-1 (Tab. 1), 44 belonging to 10 species at site SM-2 (Tab. 2), 118 belonging to 12 species at site SM-3 (Tab. 3), 7 belonging to 3 species at site AS-1 (Tab. 4), 11 belonging to 3 species at site AS-2 (Tab. 5) and 7 belonging to 3 species at site AS-3 (Tab. 6). Spiders were recorded down to a depth of 120 cm. *Cicurina cicur* was the most abundant species. Species that were clearly tied to surface habitats (e.g., *Agroeca cuprea*) were usually recorded only a few tens of centimetres deep. Some individual records can be considered as accidental, e.g. the record of *Linyphia hortensis* at a depth of 110 cm, due to the fact that it is a typical shrub layer inhabitant (Buchar & Růžička 2002). *Cicurina cicur*, *Mioxena blanda*, *Palliduphantes pallidus*, *P. alutacius* and *Syedra myrmicarum* were depigmented with fully developed eyes. Four species were depigmented with reduced eyes and were clearly adapted to life in subterranean habitats. These species represent objects of our special interest.

Hahnia microphthalma

Material: Jenišovice-Mravín (SM-2), 25 October 2013-18 April 2014 1♀; 28 April-29 September 2015, 1♀. This species is reported for the first time from the CZECH REPUBLIC.

Posterior median eyes reduced (Fig. 3a). Szita et al. (1998) and Hänggi & Stäubli (2012) found various stages of eye reduction in their material, and also differences in the form of the translucent copulatory ducts. The picture of the copulatory ducts of the epigyne of our specimens is in agreement with that of the type specimen (Fig. 3b; cf. Snazell & Duffey 1980: Fig. 3).

Snazell & Duffey (1980) described the species according to two records from Great Britain. Hänggi & Stäubli (2012) summarized other records: three in Germany, one in Switzerland, and one in Hungary (Fig. 4). British specimens were collected in chalk grassland and in a field with a clay soil over-

Tab. 1: The species assemblage at SM-1. The number of males, females and juveniles (♂♂/♀♀/juv. [if determinable]) and the depth range (in cm) are shown. The species considered microphthalmic are shown in bold.

Species	♂♂/♀♀/juv.	Depth range
Lepthyphantes leprosus	0/1	10
Panamomops mengei	1/0	10
Tenuiphantes flavipes	6/1	10–20
Histopona torpida	0/4	10–40
Phrurolithus festivus	1/1	10–40
Amaurobius jugorum	1/2/3	10–70
Cicurina cicur	31/22/6	10–70
Harpactea rubicunda	12/27	10–80
Agroeca cuprea	1/0	20
Diplostyla concolor	4/4	20–30
Micrargus herbigradus	2/2	20–30
Coelotes terrestris	1/1	20–40
Liocranum rupicola	1/0	30
Ozyptila praticola	0/1	30
Harpactea lepida	1/0	40
Walckenaeria nudipalpis	0/1	40
Mioxena blanda	3/1	40–60
Syedra myrmicarum	0/2	50–80
Porrhomma microps	**5/4**	**70–100**
Mastigusa arietina	0/1	90

Tab. 2: The species assemblage at site SM-2

Species	♂♂/♀♀/juv.	Depth range
Clubiona terrestris	1/0	40
Coelotes terrestris	1/0	40
Histopona torpida	0/1	40
Micrargus herbigradus	6/3	40-70
Cicurina cicur	6/3/11	40-110
Porrhomma microps	**0/1**	**50**
Hahnia microphthalma	**0/2**	**50-70**
Amaurobius jugorum	0/1	80
Porrhomma cambridgei	**4/3**	**80-120**
Linyphia hortensis	0/1	110

Tab. 3: The species assemblage at site SM-3

Species	♂♂/♀♀/juv.	Depth range
Coelotes terrestris	1/0	10
Diplostyla concolor	1/5	10
Inermocoelotes inermis	1/0	10
Nusoncus nasutus	0/1	10
Harpactea lepida	1/2/3	10–40
Microneta viaria	0/2	10–50
Palliduphantes pallidus	3/3	10–100
Cicurina cicur	40/24/16	10–140
Harpactea hombergi	0/0/1	20
Centromerus sellarius	0/1	30
Porrhomma egeria	**1/8/3**	**70–140**

Tab. 4: The species assemblage at site AS-1

Species	♂♂/♀♀/juv.	Depth range
Robertus lividus	0/1	10
Palliduphantes alutacius	0/1	10
Porrhomma cambridgei	**3/1/1**	**30–80**

Tab. 5: The species assemblage at site AS-2

Species	♂♂/♀♀/juv.	Depth range
Cicurina cicur	4/1/1	10
Palliduphantes alutacius	0/2	20
Porrhomma microps	**1/1/1**	**40–50**

Tab. 6: The species assemblage at site AS-3

Species	♂♂/♀♀	Depth range
Palliduphantes alutacius	2/2	20
Syedra myrmicarum	1/1	20
Porrhomma cambridgei	**0/1**	**120**

lying chalk. Records in Germany were situated on sandstone and limestone bedrock (Sührig et al. 1998). The Hungarian locality was situated in an old field on loess (Szita et al. 1998).

All previous specimens were collected on the surface by pitfall traps, photoeclectors or by sweeping. Snazell & Duffey (1980) conclude that some of the characteristics of the spider suggest a subterranean habitat. We document for the first time that *H. microphthalma* inhabits the soil at a depth of about 50-70 cm.

Porrhomma cambridgei
Material: Jenišovice-Mravín (SM-2), 18 April-13 August 2014, 1♂ 1♀; 21 November 2014-28 April 2015, 2♂; 28 April-29 September 2015, 1♂ 2♀. Lednice (AS-1), 29 June-5 November 2014, 1♂ 1j.; 5 November 2014-17 May 2015, 2♂ 1♀. Pardubice (AS-3), 28 April-23 September 2015, 1♀.

Pickard-Cambridge (1871) noted that the species "*Linyphia*? *oblonga*" is characterized by "eyes very small". Based on the vulva structure, Millidge & Locket (1952) synonymized this microphthalmic form with *Porrhomma oblitum* (O. P.-Cambridge, 1871). Finally, Merrett (1994) removed it from synonymy with *P. oblitum* and revalidated it as a separate species *P. cambridgei* Merrett, 1994. It is clearly characterized by femora I and II without dorsal spines, a cephalothorax width < 0.58 mm, and reduced eyes. It has been recorded from Great Britain, Germany, Switzerland, northern Italy and the Czech Republic (Thaler et al. 2003).

We and Růžička et al. (2011, sub. *P.* aff. *myops*) captured this species in sandy marlite terrain and in alluvial soils at a depth of 35-120 cm. Thaler et al. (2003) collected this species on tree bark in the Bohemian Karst and we also obtained several specimens from conglomerate terrain and from karst caves.

Porrhomma egeria
Material: Kounov (SM-3), 5 April-14 July 2014, 1j.; 21 April-25 September 2015, 1♂ 8♀ 2j.

Porrhomma egeria inhabits caves and scree slopes, it also occurs in mountain spruce forests and subalpine zone (Buchar & Růžička 2002). It is fairly widespread in north-western, central and northern Europe (Nentwig et al. 2015). Its abundant occurrence in creviced rock is recorded for the first time.

Porrhomma microps
Material: Jenišovice-Mravín (SM-1), 21 November 2014-28 April 2015, 2♀; 28 April-29 September 2015, 5♂ 2♀. Jenišovice-Mravín (SM-2), 13 August-21 November 2014, 1♀. Znojmo (AS-2), 20 August 2014-11 May 2015, 1♂ 1♀ 1j.

Porrhomma microps is widespread in continental Europe (Nentwig et al. 2015). It inhabits leaf litter in floodplain forests and was also recorded in caves, not deeper than 10 m. It was also recorded in the soil on a sandy marlite at a depth of 55-135 cm by Laška et al. (2011), and in lowland forest at a depth of 5-45 cm by Růžička et al. (2011). The specimen reported by Růžička et al. (2013, Fig. 6) from a depth of 80 m was misidentified and is actually *P. profundum* M. Dahl, 1939.

Habitats

Sandy marlite. In a clay soil at site SM-2, we captured three microphthalmic species together: *Porrhomma microps*, *Hahnia microphthalma* and *P. cambridgei* (Tab. 2). We captured *P. egeria* in a layer of fissured rock at site SM-3 (Tab. 3).

Porrhomma microcavense Wunderlich, 1990 was reported from a sandstone landscape for the first time in the Czech Republic (Buchar & Růžička 2002). However, in detail, it was recorded above a sandy marlite layer. Furthermore slightly microphthalmic specimens of *Oreonetides quadridentatus* (Wunderlich, 1972) were captured by Laška et al. (2011; sub *Maro* sp.) at a depth of 45 and 65 cm in clay soil on sandy marlite bedrock, together with *Porrhomma microps*.

Alluvial soils. We collected *P. cambridgei* and *P. microps* in alluvial soil/sand in three different localities in lowland forests near a river. In the same habitat, Růžička et al. (2011) collected these two species together. Together with *H. microphthalma*, these two species can be considered soil spiders.

Concluding remarks

The importance of shallow subterranean habitats for the evolution of subterranean life is well known (Růžička 1999, Giachino & Vailati 2010, Růžička et al. 2013, Culver & Pipan

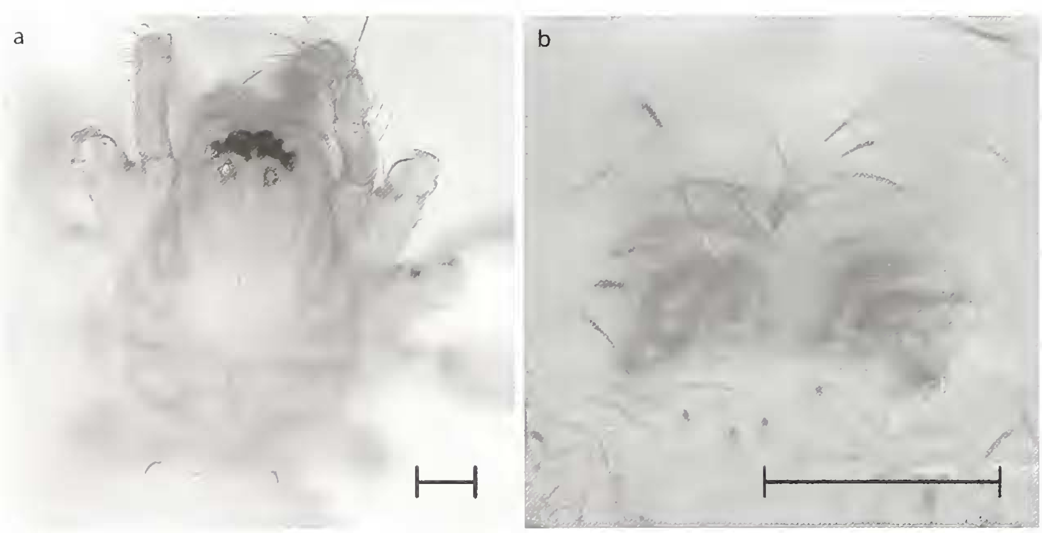

Fig. 3: *Hahnia microphthalma*; **a.** eye arrangement; **b.** epigyne. Scale line 0.1 mm

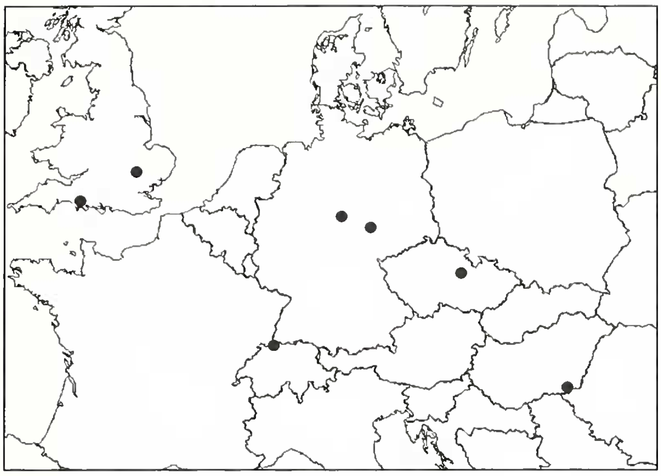

Fig. 4: *Hahnia microphthalma*: map of the known records

2014) and has been repeatedly documented in recent years. Using pipe traps, Deltshev et al. (2011) collected spiders in soils down to the depth of 80 cm in the Bulgarian mountains. *Zangherella relicta* (Kratochvíl, 1935), described from a cave in Montenegro, was recorded, which represents the first record of the family Anapidae in Bulgaria. Gilgado et al. (2015) collected the troglomorphic millipede *Typhlopsychrosoma baeticaense* (Mauriés, 2013), known from caves, in mountain screes and concluded that some subterranean species might have surprisingly wide distribution areas, and that study of shallow subterranean habitats will surely improve our poor knowledge on subterranean biodiversity.

There is a wide spectrum of sedimentary rocks containing variable amounts of clay and silt designated as marl or marlite. Their properties depend on mineralogical composition and diagenesis. In the Alicante region (Spain), the marl offers no suitable insterstices for a subterranean fauna, and marl layers constitute physical barriers to the movement of subterranean animals (Ortuño et al. 2013, Gilgado et al. 2015). On the other hand, in the Czech Republic, the indurated sandy marlite forms a fissure network. This fissure network, together with soils originating from this bedrock, constitutes a subterranean habitat that seems to be very suitable for the subterranean fauna, according to our findings.

In subterranean biology, there is a common idea that alluvial plains are barriers to subterranean faunas, and that they do not have suitable spaces (Uéno 1987). However, this depends on the size of the sand and gravel grains. Christian (1998) recorded a subterranean palpigrade *Eukoenenia austriaca* (Hansen, 1926) (usually found in caves) in the bottom substrate of the tombs of St. Stephen's Cathedral in Vienna. These catacombs were dug down to the Pleistocene gravel of the Danube river. Gilgado & Ortuño (2015) recorded a subterranean zygentomid *Coletinia maggii* (Grassi, 1887) (usually found in surface habitats, ant nests and caves) in a subsoil gravel layer in an alluvial plain in northern Spain. We collected subterranean spiders in three different alluvial plains. These findings suggest the possibility that alluvial deposits might represent 'connectors' between other subterranean habitats, at least for some subterranean animals. Moreover, in the locality AS-1, we collected not only the subterranean spider *Porrhomma cambridgei* at a depth of 30–80 cm, but also a pale subterranean *Niphargus* sp. at a depth of 0–90 cm. Crustaceans thus migrated into soil horizons from shallow aquatic interstitial habitats at the time of flooding.

The modified space around the pipe can represent an artificial corridor through which invertebrates can migrate in a vertical direction. Nevertheless, the vertical distributions of spiders are clearly species-specific as also documented by Laška et al. (2011). In both cases of the common occurrence of *P. microps* and *P. cambridgei* (our site SM-2 and Růžička et al. 2011), the smaller species *P. cambridgei* occupies deeper soil horizons.

On the other hand, the soil structure is destroyed during installation of the traps, and fine crevices are closed. The reconstruction of the network of voids can take several years, as we infer by the catching of the first adults of *P. egeria* after two years of investigation.

Finally, we would like to recommend the use of complex pipe traps, which enables precise documentation of the depth distribution of species. We would like to emphasize that to document the occurrence of troglomorphic invertebrates, data on the subterranean habitat (not only data on surface habitat, e.g. plant associations) are important.

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Appendix

Taxonomic survey of species collected. **Dysderidae**: *Harpactea hombergi* (Scopoli, 1763), *Harpactea lepida* (C. L. Koch, 1838), *Harpactea rubicunda* (C. L. Koch, 1838); **Theridiidae**: *Robertus lividus* (Blackwall, 1836); **Linyphiidae**: *Centromerus sellarius* (Simon, 1884), *Diplostyla concolor* (Wider, 1834), *Lepthyphantes leprosus* (Ohlert, 1865), *Linyphia hortensis* Sundevall, 1830, *Micrargus herbigradus* (Blackwall, 1854), *Microneta viaria* (Blackwall, 1841), *Mioxena blanda* (Simon, 1884), *Nusoncus nasutus* (Schenkel, 1925), *Palliduphantes alutacius* (Simon, 1884), *Palliduphantes pallidus* (O. P.-Cambridge, 1871), *Panamomops mengei* Simon, 1926, *Porrhomma cambridgei* Merrett, 1994, *Porrhomma egeria* Simon, 1884, *Porrhomma microps* (Roewer, 1931), *Syedra myrmicarum* (Kulczyński, 1882), *Tenuiphantes flavipes* (Blackwall, 1854); *Walckenaeria nudipalpis* (Westring, 1851); **Agelenidae**: *Coelotes terrestris* (Wider, 1834), *Histopona torpida* (C. L. Koch, 1834), *Inermocoelotes inermis* (L. Koch, 1855); **Hahniidae**: *Hahnia microphthalma* Snazell & Duffey, 1980; **Dictynidae**: *Cicurina cicur* (Fabricius, 1793); *Mastigusa arietina* (Thorell, 1871); **Amaurobiidae**: *Amaurobius jugorum* L. Koch, 1868; **Liocranidae**: *Agroeca cuprea* Menge, 1873, *Liocranum rupicola* (Walckenaer, 1830); **Phrurolithidae**: *Phrurolithus festivus* (C. L. Koch, 1835); **Thomisidae**: *Ozyptila praticola* (C. L. Koch, 1837).